An Examination of the Geologic Features of Rock and Pipestone Counties, Southwestern Minnesota, and their economic and environmental implications.

by

Rachel A. Eustice

A Senior thesis submitted to fulfill the requirements for the degree of B.S. in Geology, 1986

The Ohio State University

Thesis Advisor

Abstract: The rock outcrops and glacial features exposed in Rock and Pipestone counties in southwestern Minnesota display unusual combinations of sedimentary features and occupy a strategic position for interpreting regional stratigraphic and tectonic events. Geologists have only recently begun to systematically study the area's features, and much of the past research has overlooked stratigraphic relationships and sedimentary structures, and instead emphasized the historic and economic aspects of the two counties' geologic deposits. Indeed the historic and economic aspects of the area's geologic features are extremely important, and to fully study the area and its geologic resources it is necessary to investigate the historic, economic, and environmental impact that the area's residents have had. This paper examines the stratigraphy and probable origins of the area's geologic deposits, and evaluates the area's resources with respect to their historic, economic, and environmental implications.

INTRODUCTION

Rock and Pipestone Counties are located in Southwestern Minnesota, along the South Dakota and Iowa borders (Figure 1). This location places the counties near the crest of the Coteau des Prairies, a topographic highland who relief has played a major role in controlling recent deposition and drainage (Figure 2), (Wright, 1972). The area has sedimentary deposits ranging in age from Precambrain (Early Proterozoic) to Pleistocene. These deposits are overlain by thick organic-rich Mollisols which were formed when thick stands of prairie grasses developed on till and loess. Soil composition varies slightly within the area, with soils formed on top of Wisconsinan tills being less unifrom than those formed on Kansan materials (Thiel, 1944). This rich soil, combined with a moderate climate with approximately 26 inches of annual precipitation has produced highly productive farmland. Approximately 75 per cent of the land in the two counties is used in agriculture,

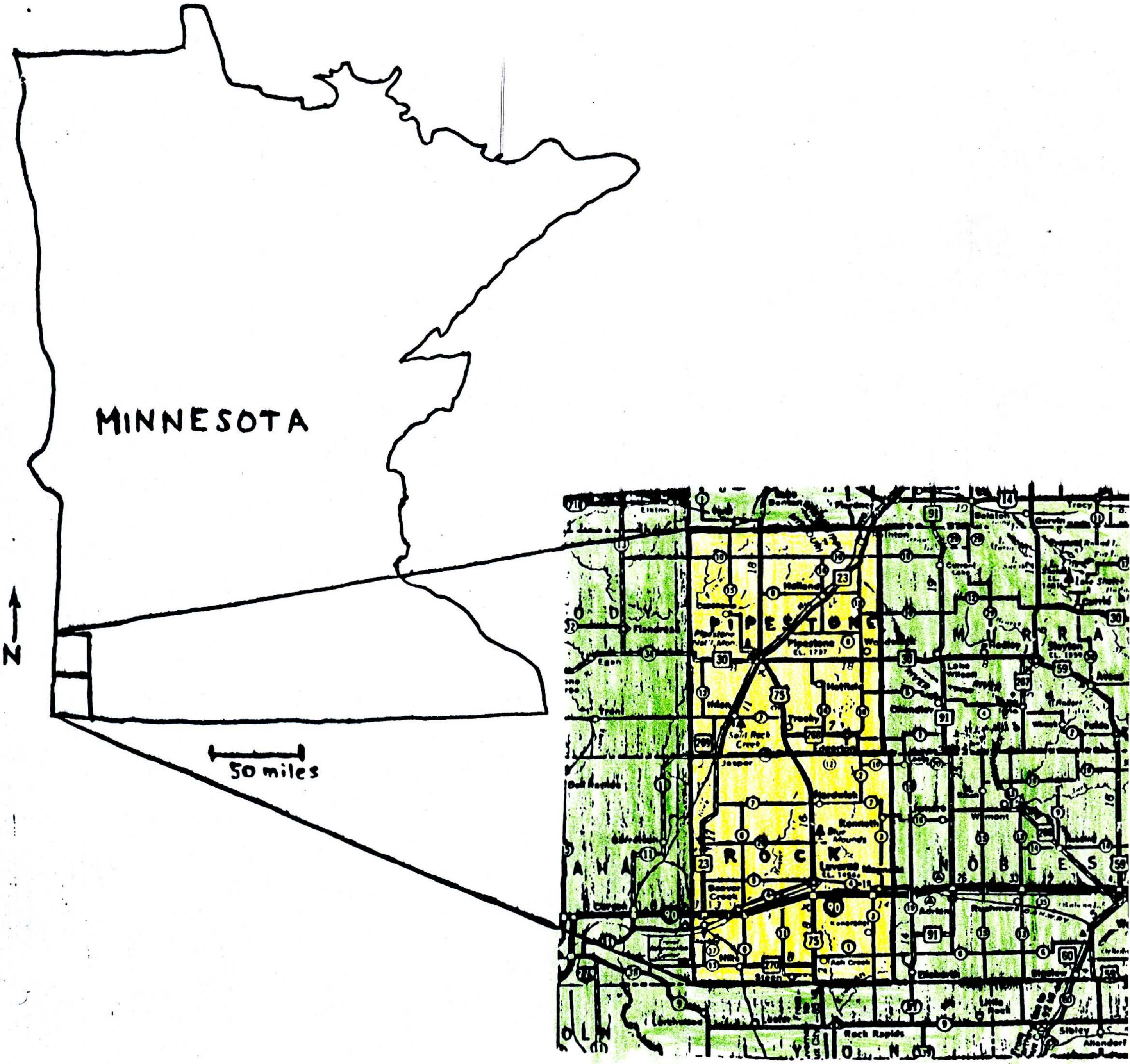

Figure 1: Map showing the location of Rock and Pipestone Counties and their major towns. (After Minnesota State Highway Department, 1985)

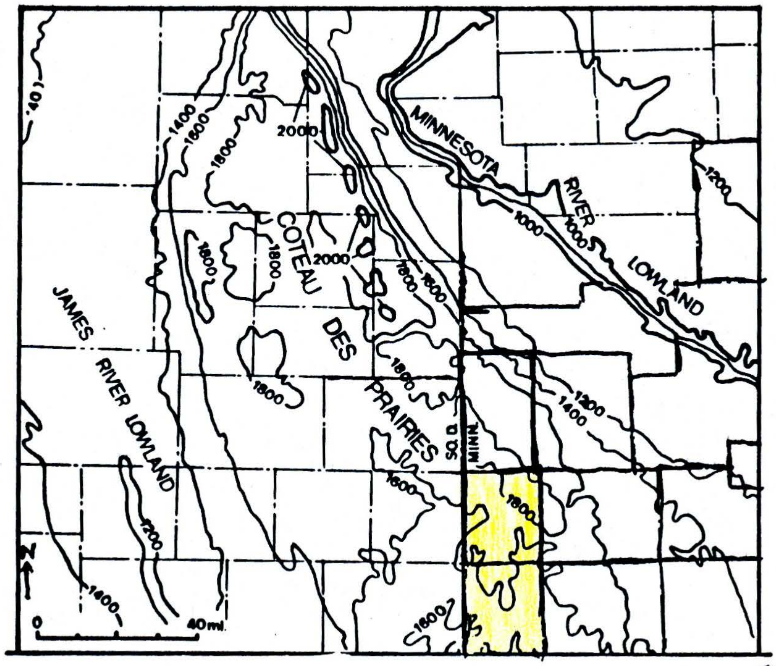

Figure 2: Map of the Coteau des Prairies. Rock and Pipestone Counties are shown in yellow. Northwest-southeast trending elevations mark relief associated with end moraines (After Voyageur Press, 1984)

with the primary crop being corn (Onstad, et al., 1982). The remaining 25 per cent of the land is either urban or has extensive rock outcrops which limit its suitability for farming. The majority of this land has been developed into parks and recreational facilities for the 22,393 residents of the two counties (Dept. of Commerce, 1980). Although 75 per cent of the land is farmed, much of this land has been manually cleared of large slabs of rock and glacial boulders, which would destroy farm equipment. Basically, the geologic deposits of till and loess help create productive, economically profitable farmland, while outcrops of Precambrian and Cretaceous sedimentary rocks often create difficulties in utilizing the land for crop production. These outcrops are, nonetheless, extremely important not only because they provide valuable clues to past geologic environments, but also because they have played a significant role in the history and economy of the area.

SEDIMENTARY ROCK OUTCROPS

Rock formations of Precambrian (Late Proterozoic) and Middle-Late Cretaceous age outcrop within Rock and Pipestone counties. The Precambrian Sioux Quartzite is much thicker and outcrops much more extensive than the Cretaceous formations in the area, which are exposed in unconsolidated, scattered outcrops. The Siouz Quartzite is primarily composed of well rounded quartz grains that have been cemented by hot silicic fluids which contained trace amounts of Iron, which gives the Quartzite a reddish-pint to purple color. The percolation of these hot silicic fluids through the quartz sandstone did not deform the sediments, which contain abundant sedimentary structures, including various types of cross-bedding, ripple marks, dessication cracks, and parallel beds (Figure 3), (Morey, et al., 1984). Although the Sioux is generally refered to as a quartzite, the formation actually contains a variety of grain sizes, and thin beds and lenses of mudstone, claystone, and conglomerate outcrop within the two county area. At Pipestone National Monement, one thin layer of altered mudstone outcrops within the quartzite that has drawn attention to the area's geologic deposits because the mudstone, often called Pipestone or Catlinite, was carved by native American Indians into peace pipes (Berg, 1938). Despite the historical emphasis on the Pipestone or Catlinite, both mudstone and conglomerate are only minor constituents of the formation, which is composed of approximately 80 per cent quartz sand (Figure 4), (Ojakangas, et al., 1984).

Neither the base nor the top of the Sioux Quartzite is exposed, and a wide variety of estimates of the quartzite's thickness have been made. Early scientists used regional dips and outcrop patterns to estimate that the quartzite was over 8000 feet thick (Austin, 1972), but recently it has been discovered that the quartzite does not have a consistent regional dip, and the thickness itself varies substantially within short distances (Ojakangas, et al., 1984). Geophysicists now propose that a series of faults appearing in the magnetic basement in Southern Minnesota have produced offset within the formation, and the complexities associated with changing dips and varying thickness (Southwick and Mossler, 1984), (Figure 5). These basement faults split the Sioux Quartzite into three distinct "basins", which are associated with the erosion of

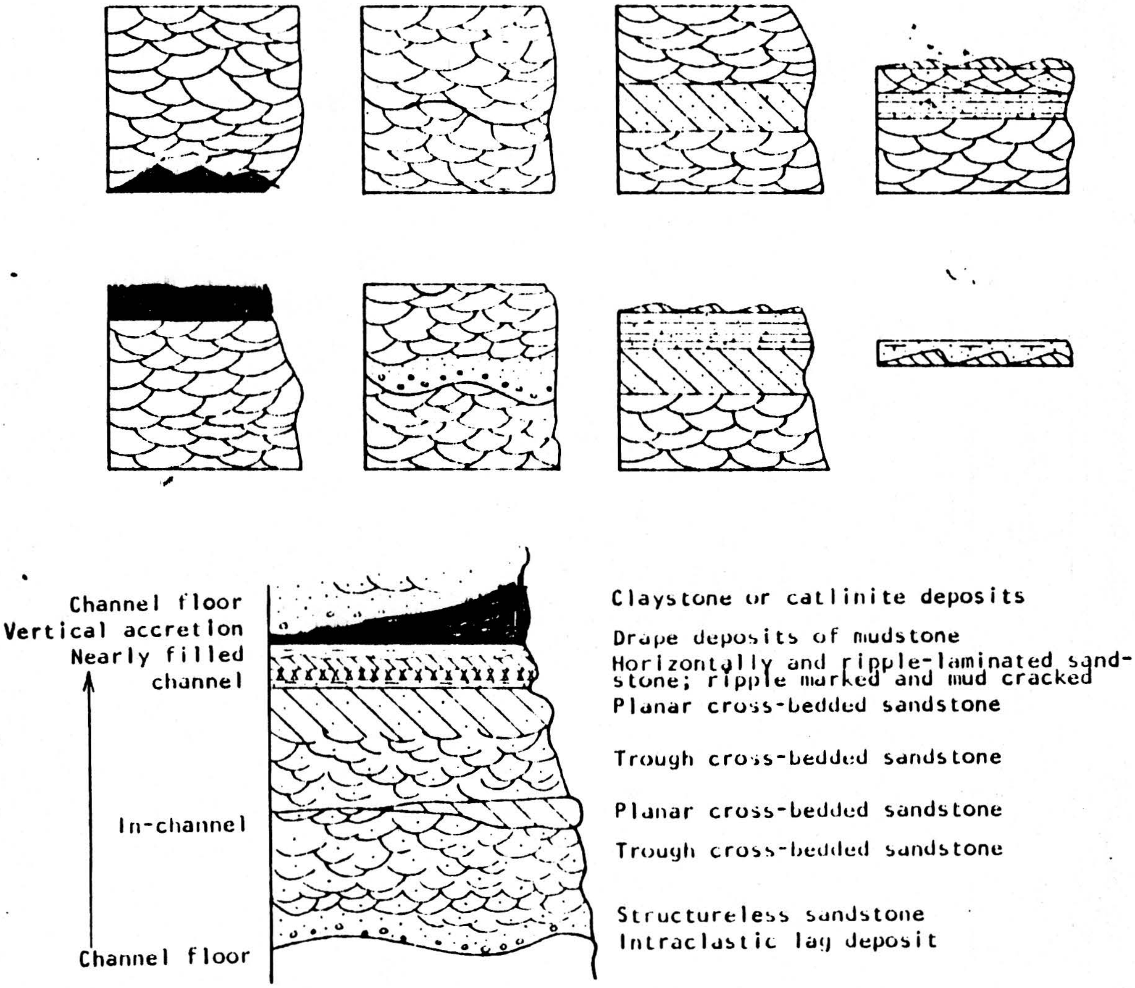

Figure 3 Observed combinations of sedimentary structures in the Sioux Quartzite as exposed in and around Pipestone National Monument and a composite vertical profile inferred from them. (After Morey, 1984).

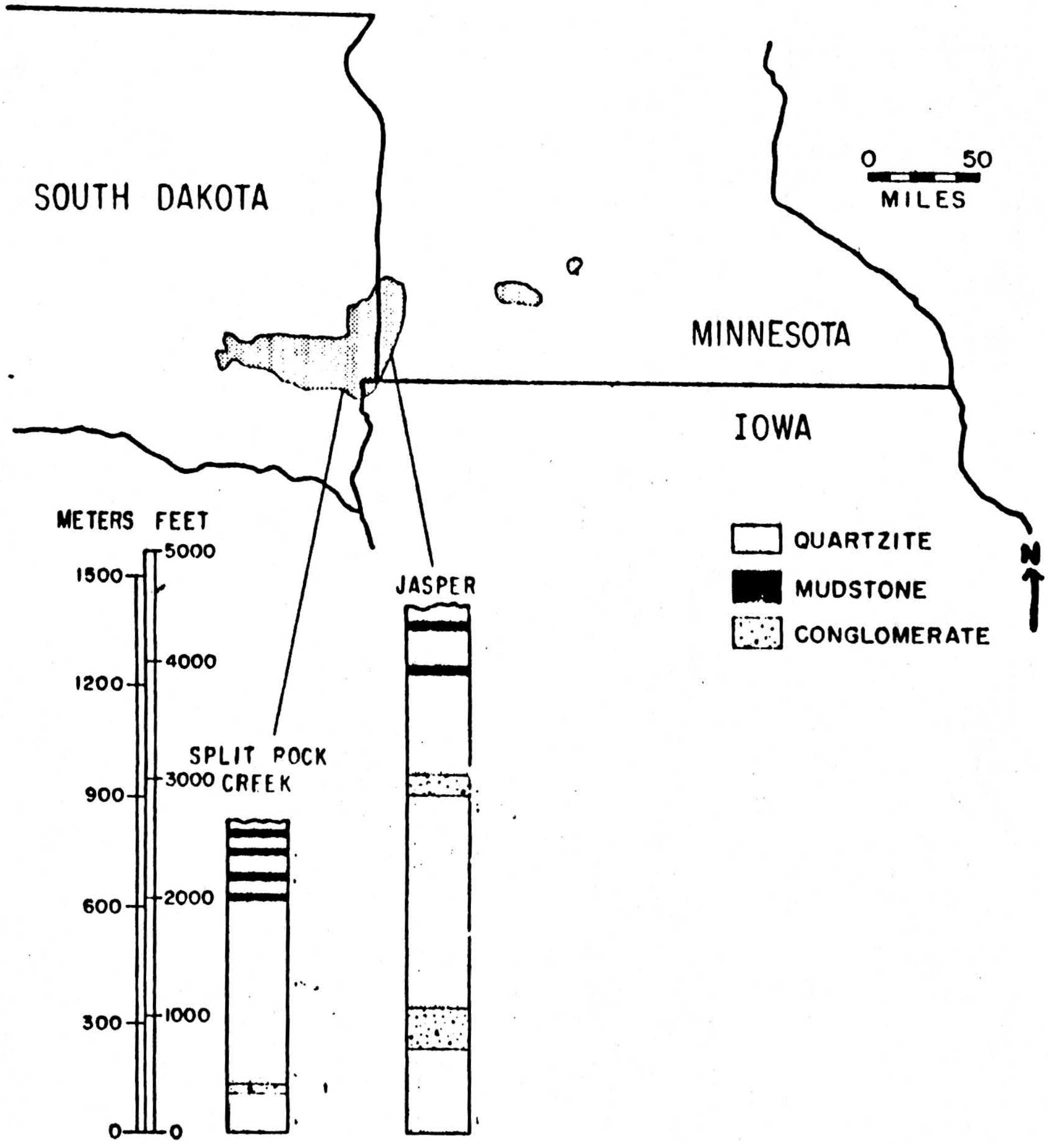

Figure 4: General location map showing sections of Sioux Quartzite and their relative proportions of Quartzite, Conglomerate, and Mudstone (After Ojakangas, et al, 1984)

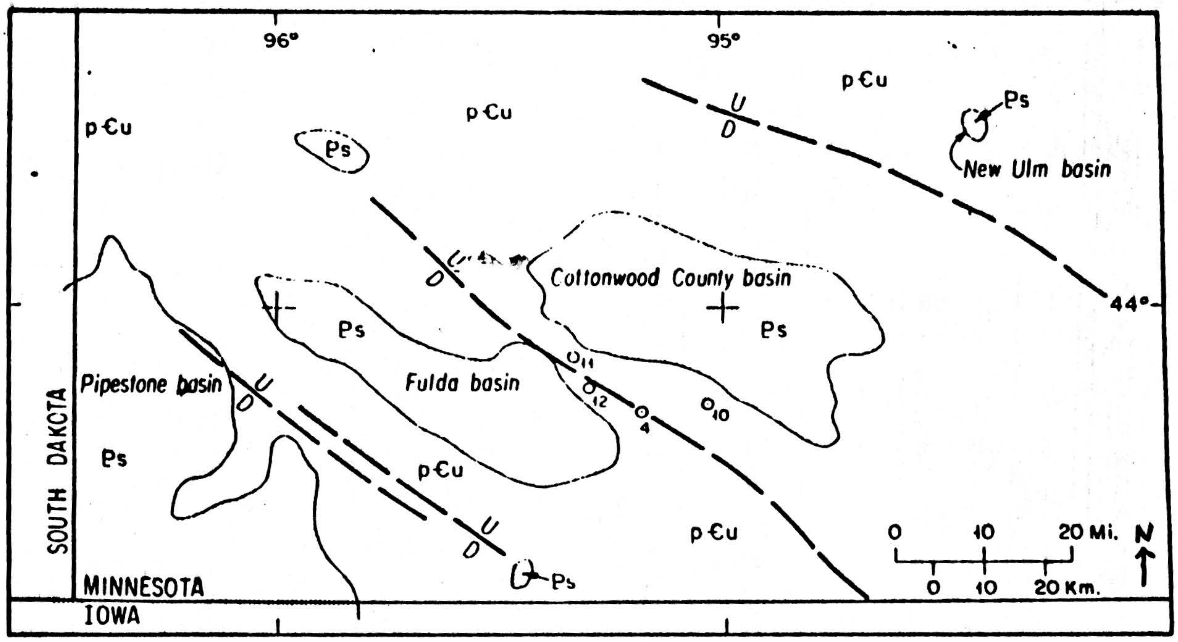

Figure 5: Prepaleozoic subcrop map showing proposed magnetic basement faults and the associated basins (From Southwick and Mossler, 1984).

offset deposits before the Sioux was lithified. These basins are inferred by magnetic anomalies, but very little evidence exists to support the faulting within the Sioux deposits themselves (Southwick & Mossler, 1984).

Early scientists assumed that the Sioux Quartzite was deposited in a gently subsiding basin or along a subsiding oceanic shelf. This assumption was largely made to explain the great thickness that was then attributed to the Sioux Formation, as well as some of its more prominent sedimentary features, such as symmetric ripple marks (Austin, 1972). Currently most geologists accept the theory that most, if not all, of the Sioux Quartzite was deposited in a distal braided fluvial-alluvial environment (Figure 6), (Ojakangas, et al., 1984). The cross bedding, ripple marks, dessication cracks, and parallel bedding relationships, as well as the various grain size distributions all support this theory. Nonetheless, many researchers question this interpretation because they realize that the vast quantities of mature sand grains were probably not available at that time. Although this is a distinct possibility, this in itself does not rule out the possibility of deposition in a braided fluvial environment. Ojakangas, for example, points out that the Precambrain landscape lacked vegitation which could result in the rapid maturation of sand grains. He proposes that the Sioux Quartzite was formed in a braided fluvial-alluvial environment on a easily weathered grus like soil (oJakangas, et al., 1984). This theory seems credible, but further research is still necessary to determine its absolute validity.

The Sioux Quartzite, after cementation, is extremely hard, and resistant to weathering. Nonetheless over long time periods,

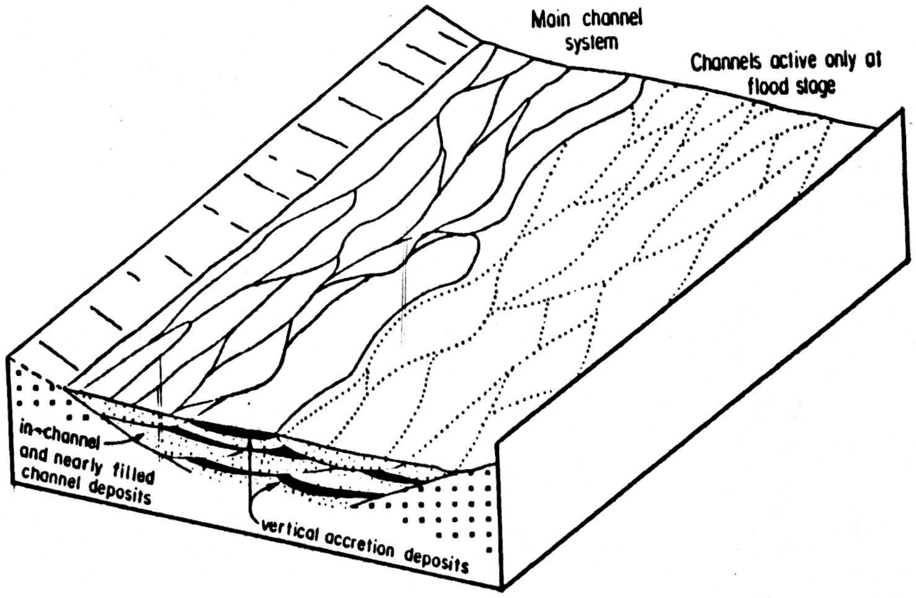

Figure 6: Diagram showing a typical braided stream and its associated deposits (After Morey, 1984).

the quartzite does weather, and forms coarse rounded gravels. These rounded clasts are the primary constituent of the unconsolidated Early Cretaceous residuum that outcrops within the area (Figure 7). These deposits, however, are not very common, and the entire Cretaceous system in Rock and Pipestone Counties is represented by a maximum of 600 feet of rock, the majority of which is Late Cretaceous in age. These Late Cretaceous sediments vary greatly in thickness, and outcrops tend to be discontinuous. Thus the Cretaceous Dakota Sandstone, the Colorado Group formations, and the Pierre Shale do not form scenic canyons or spectacular ridges as they do in states further west. In these western states these formations represent shallow marine deposits in the Cretaceous interior seaway, and are remarkable continuous over hundreds of miles. In southwestern Minnesota, on the other hand, these formations are composed of coarse white sands alternating with lignite and ma marine shales. These Late Cretaceous sediments are currently interpreted as being deltaic or continental in nature, although this interpretation is not based on strong evidence. Most theories about the nature or depositional environment of Late Cretaceous material relies on regional mapping, and the relationships between regional stratigraphic and tectonic events (Figure 8). Thus much more research needs to be done to determine the exact nature and geologic position of the Cretaceous sedimentary units in southwestern Minnesota (Austin, 1972).

The last type of sedimentary deposit that this paper will explore is the glacial deposits associated with various glacial advances and retreats. The glacial history of the two counties is not simple, because each glacial advance and retreat left

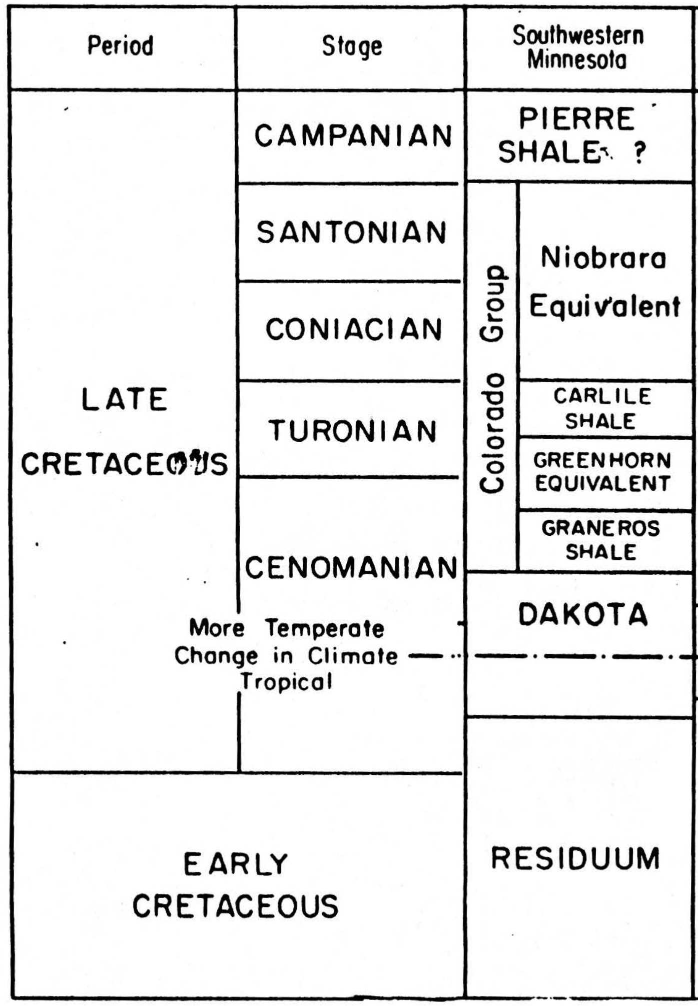

Figure 7: Diagram showing the names and ages of the Cretaceous strata in Southwestern Minnesota. (After Sims, 1974)

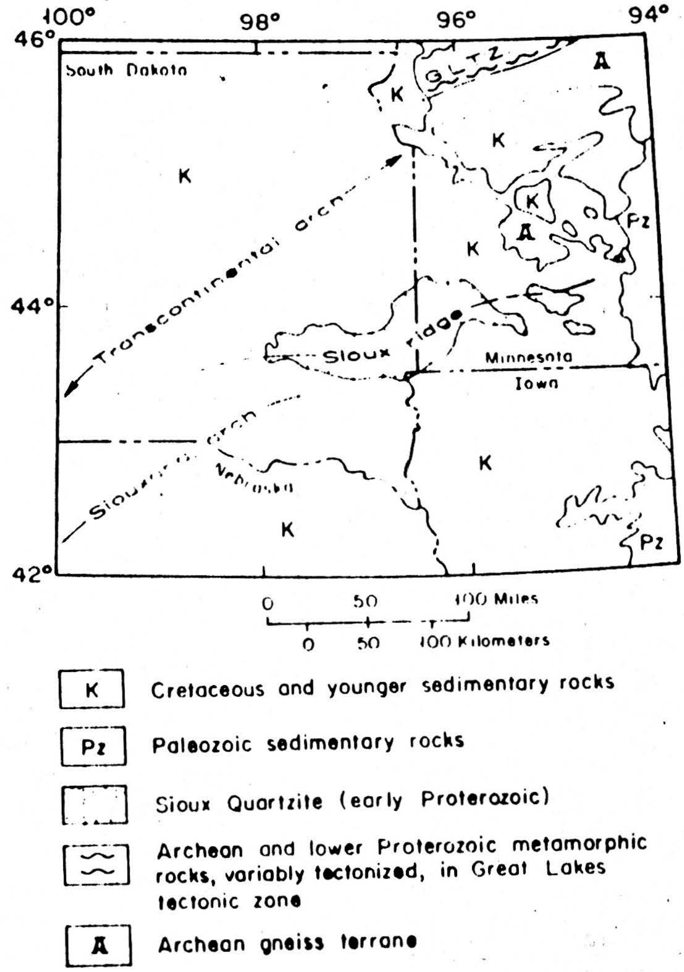

Figure 8: Regional Map showing the distribution of Cretaceous rocks with respect to major structures. (After Sims, 1974)

unique deposits of till, outwash, loess, and glacial lacustrine materials. In addition, the glaciations polished the surface of outcrops, produced several sets of glacial striae, each trending at a different angle, and cut meltwater channels into the existing bedrock. These complex features confused many geologists, and a variety of contradictory literature has been produced, each assigning the glacial features different names and ages.

One of the most striking contradictions was the fact that several published maps claim that Rock County contains no glacial drift, while in fact it has over 200 feet of drift in some places (Figure 9). Rock County's superficial deposits are Kansan Till overlain by Wisconsinan loess. The Kansan Till is much more homogeneous than the younger Wisconsinan tills, for it frequently only contains boulders and cobbles of the Sioux Quartzite, and does not contain the variety of igneous and sedimentary glacial erratics (Flint, 1955).

The Wisconsinan glaciation advanced into Pipestone county, where it encounter the Coteau des Prairies. The elevation associated with the Coteau is slight, but nonetheless this slight topographic relief was enough to halt the glacier's advance. The Bemis moraine, the end moraine of the Tazewell stage of the Wisconsinan glaciation cuts across Pipestone County (Figures 10 and 11). The Altamount moraine associated with the Cary stage of the Wisconsinan glaciation roughly parallels the Bemis moraine, and is made of a younger till which just enters the northeast corner of Pipestone County. These moraines and their associated tills each have a slightly different age and slightly different physical properties, which have made

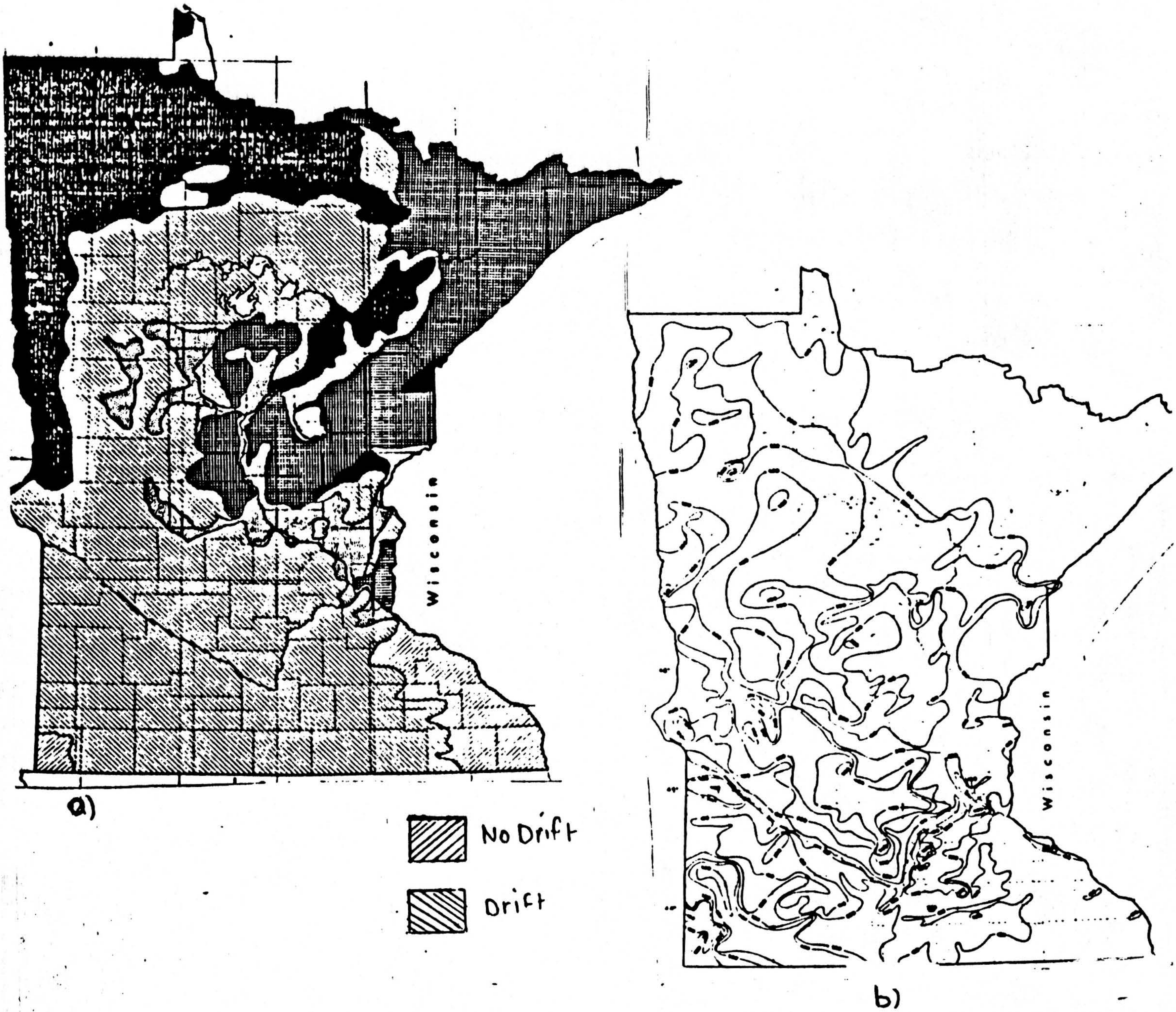

Figure 9: a) Map showing incorrect assumption that no drift is present within Rock County, and b) Map showing thickness of drift present. Map b shows from 100 to 200 feet of drift in Rock County. (After Matsch, 1972)

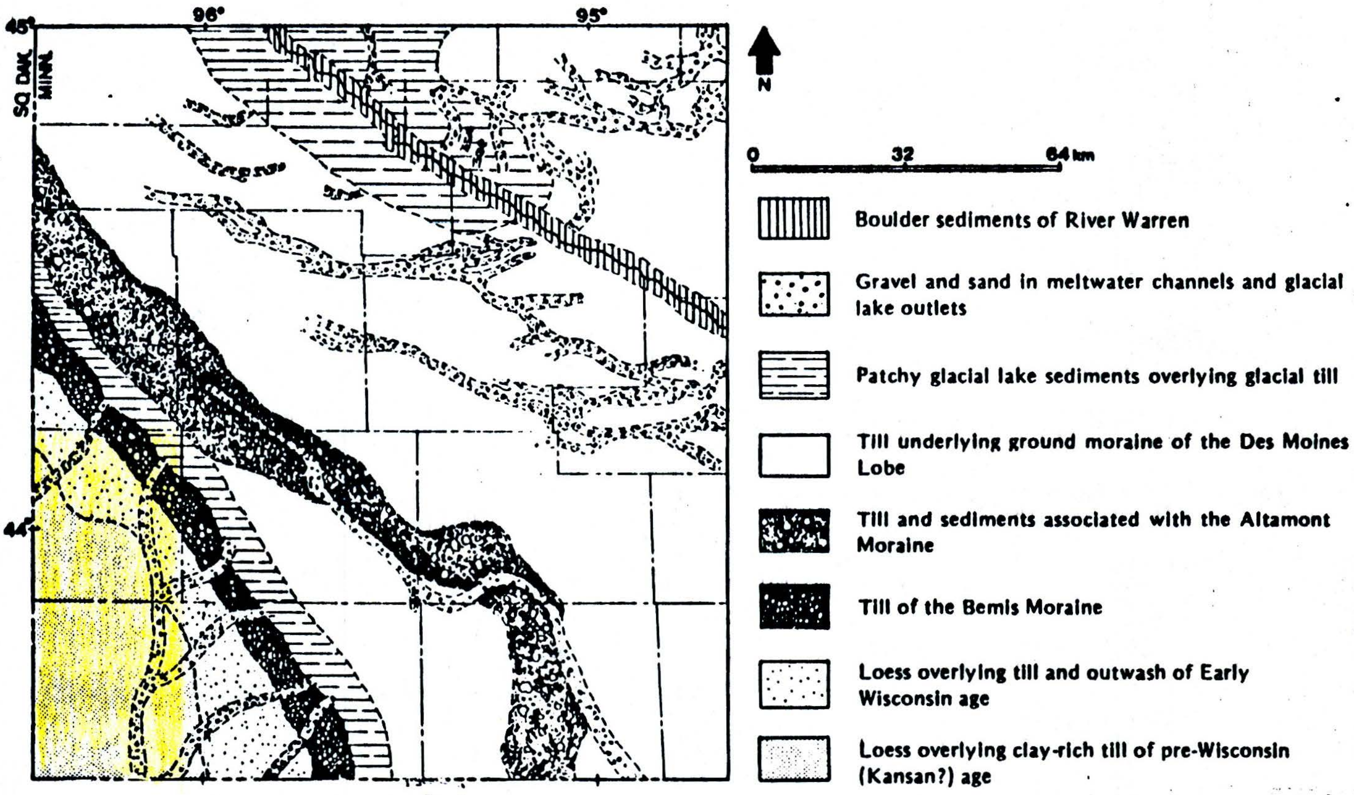

Figure 10: Map showing distribution of Glacial deposits in Southwestern Minnesota (After Voyageur Press, 1984)

PRE-WISCONSIN NONGLACIAL DEPOSITS

EVENTS: WEST OF MISSOURI RIVER TRENCH	EVENTS: IN MISSOURI RIVER TRENCH	LITHOLOGIC UNITS AND ZONES OF WEATHERING AND SOIL EAST OF MISSOURI RIVER TRENCH	TIME UNITS (Relative lengths not implied)		
Erosion	Erosion	Soil	Recent epoch		
Valley filling	Deposition of fine-grained valley fill	Mankato loess; Mankato drift	Mankato glacial subage	Wisconsin age	Pleistocene epoch
Erosion	Erosion	Erosion	Cary-Mankato interval		
Valley filling	Deposition of outwash, mostly fine grained	Cary loess; Cary drift; EROSIONAL UNCONFORMITY	Cary glacial subage		
Erosion:	Erosion of most of valley fill	Weathering profile (Oxidised sediments and soil)	Tazewell-Cary interval		
Valley filling	Deposition of loess and coarse-grained outwash	Tazewell loess; Tazewell drift; Iowan loess	Tazewell glacial subage		
Deposition of Iowan loess		Iowan loess	Iowan-Tazewell interval		
Local lacustrine filling of valley	Deposition of outwash	Iowan drift; EROSIONAL UNCONFORMITY	Iowan glacial subage		
Erosion	Erosion	Weathering profile (Oxidised sediments and gumbotil)	Sangamon interglacial age		
Deposition of sand and gravel along major streams	Rapid enlargement of trench; deposition of outwash; Creation of trench by diversion	Loveland loess; Illinoian drift; Western sand and gravel (Crete formation?); EROSIONAL UNCONFORMITY	Illinoian glacial age		
Erosion accompanied by inversion of topography in places	(Trench not in existence)	Weathering profile?	Yarmouth interglacial age		
Deposition of sand and gravel along major streams		EROSIONAL UNCONFORMITY; Silty clay of Sappa formation (including Pearlette ash member) Western sand and gravel (Grand Island and Red Cloud formations); Kansan drift; EROSIONAL UNCONFORMITY	Kansan glacial age		
Erosion		Weathering profile?	Aftonian interglacial age		
Deposition of sand and gravel along major streams		Alluvial silt (Fullerton formation?) Western sand and gravel (Holdrege formation?); Nebraskan (?) drift	Nebraskan glacial age		
Protracted erosion		EROSIONAL UNCONFORMITY			
Deposition of widespread mantle of western sand and gravel		Western sand and gravel (Ogallala formation?)	Pliocene epoch		

Figure 11: Age and relationships betwwen various Pleistocene glacial deposits (From Steece, et al., 1960).

it possible to identify the various stages of glaciation within the two counties (Figure 12).

In addition to moraines and till plains, deposits of glacial outwash and lacustrine material are also present in the two counties. The glacial meltwaters associated with the Tazewell stage of the Wisconsinan glaciation built up begind the Bemis moraine, creating a small glacial lake. The release of some of these meltwaters carved wide deep channels into the quartzite deposits in Rock and Pipestone Counties, as well as in areas of Iowa and South Dakota. Some of these channels are over 90 feet deep, and create spectacular views of the Sioux Quartzite.

The geologic research connected to these glacial deposits as well as the other sedimentary formations in the area is important in determining the age and nature of the deposits, but historic, economic, and environmental aspects of the area's geology are also vital in understanding the development of the area's geologic resources.

HISTORY OF THE AREA'S GEOLOGIC DEPOSITS

The human history of Rock and Pipestone Counties has, to a large extent been shaped by the nature and location of the area's geologic deposits. The first known settlements in the area, for example, were established in approximately 1100 AD when Native American Indians began to quarry pipestone outcrops at the Pipestone National Monument in Pipestone County. The pipestone, or Catlinite, is a soft reddish mudstone that can be carved easily into peace pipes and other ornaments. The pipestone was considered a very valuable resource, and was traded by Indian tribes throughout the

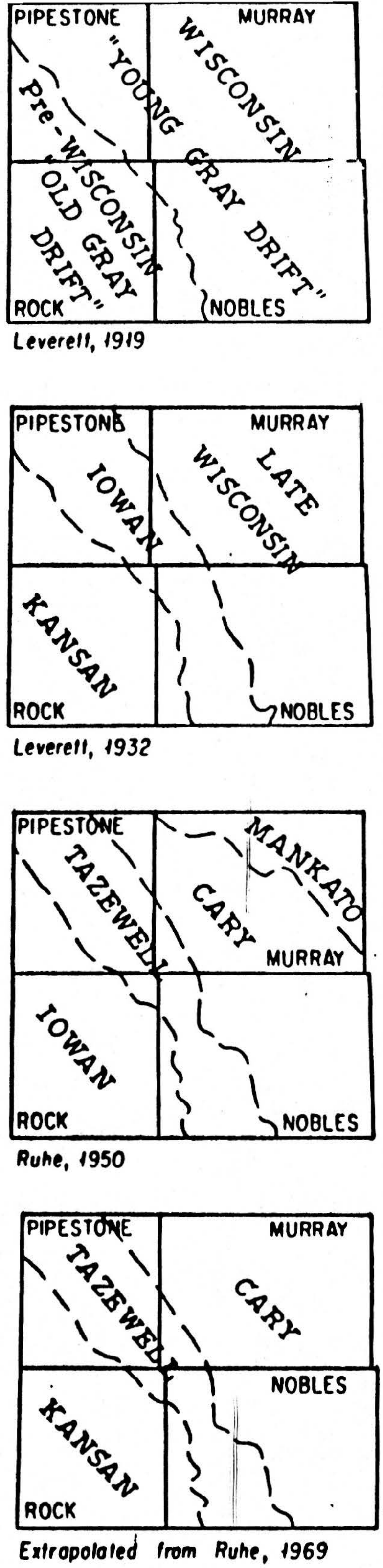

Figure 12; Map showing distribution and names of various stages of Glaciation. Note changes in Nomenclature and age relationships

(After Ojakangas and Matsch, 1982).

midwest. Henry Wadsworth Longfellow immortalized the quarry in his "Song to Hiawatha" when he wrote:

On the Mountains of the Prairie
  on the Great Red Pipestone Quarry
Gitche Manitu, the mighty,
  He, the Master of Life, descending
On the Crags of the Quarry
  Stood erect, and called to the nations
Called the tribes of men together.

Other local legends involving Indian traditions and geology abound in the area. Near the pipestone quarry, for example, three large granite boulders, called the three maidens, stand. The three rocks are said to protect the quarry, and Indians have showered gifts on the glacial erratics, which were said to contain the spirits of three Indian women who hid there during an Indian war. On a more practical note, the Indians used the cliff-like glacial meltwater channels to kill buffalo A group of Indians would isolate one buffalo from the herds that would graze in the praires and chase it until the animal was forced off a 30 foot cliff, and fell to its death (Voyageur press, 1983).

White settlement of the area began after the civil war when the homestead act opened land up for development. This land was homesteaded in 160 acre tracts on which most settlers grew corn and raised livestock. In 1888, the Jasper Stone Quarry began mining the Sioux Quartzite in Rock and Pipestone Counties. The stone, at that time, was being mined for building stone and road supports. Systematic joints within the quartzite however, made quarrying the rock for building stone unprofitable and in 1915 it began to produce aggregate for road surfacing. This mine continues to produce aggregate today and the roads around Rock and Pipestone counties are pink because of their quartzite content. The mine's main production, however, has shifted from aggregate to abrasives and grinding materials for industrial processes (Stelling, 1986). The Sioux Quartzite as it outcrops to form deep meltwater channels in Minnesota and South Dakota has also played an interesting, though historically less significant role, in that Jessie James jumped into the Rock River near Garretson, South Dakota, less than five miles from the Rock County border to avoid being caught by a posse. The town of Garretson now takes pride in this fact, and has a monument to Jessie James on the Sioux Quartzite at Devil's Gulch State Park.

ECONOMIC ASPECTS OF THE AREA"S GEOLOGY

The land around Pipestone and Rock Counties has often been overlooked by State Geological Surveys when they are addressing questions about the economic geology of the state. While it is true that neither county has significant ore deposits, the area's economic geology is still very important. Quartzite mining is done on a very small scale basis, and its profitability had decreased through the years, and they are now under threat of foreclosure (Stelling, 1986). Quartzite mining, however, is not the only manner in which the area's geologic deposits affect the economy of the area.

Agricultural production and farming are the main industries in both Rock and Pipestone Counties. Rock County's soils are formed on top of old Kansan till and Wisconsinan loess, and are extremely productive. Pipestone county's soils are formed on top of younger till, lacustrine, and outwash deposits, which are not as economically favorable as the rich loess in Rock County, but nonetheless, support a great number of farmers.

Land management and development play large roles in determining crop yields and the economic profitability of the area. In 1976, the U. S. government started building a plant to produce ethanol from crop residue and biomass in Sherman, South Dakota, less than one mile from Rock County. The governmental agricultural studies predicted that the area could remove from 35 per cent to 58 per cent of their crop residues without effecting crop yield or increasing soil erosion. This program was an economic failure for it failed to take into consideration the farmer's traditional tillage practices and the need for a long term committment to the program. In addition, the program could not predict that the oil crisis of the early 1970s would end, and that fuel would once again become more available. (Larson, 1978; Onstad, et al., 1982; Lindstrom, et al., 1978).

This program, however, did show some foresight for it did take into consideration the long term effects of crop residue removal on the environment and the economy. Many other programs are begun with short term goals, which in the long run slowly destroy the environment or the economy. In this manner, the use of urea based fertilizers, in combination with soils that had available nitrate, became hazardous because people did not see how runoff would effect the quality of the drinking water. Rock County, where the nitrate levels are extremely high at several monitered stations, must now post signs warning people of the dangers of nitrates on children and pregnant livestook. The land was not really mismanaged or developed poorly, but individuals and county officials failed to see the long term impact of their actions.

SUGGESTIONS AND CONCLUSIONS

Rock and Pipestone Counties, as their names suggest, have important rock outcrops which have played a large role in the counties' history and development. Agriculture, the main industry of both counties, is now becoming too expensive for individual farmers, and farm foreclosure is becoming a significant economic problem. In order to keep the agricultural land profitable, it is necessary to develop new programs of land use, management, and development. Cooperative ventures, where an association of farmers own and operate farm equipment may be helpful in keeping down farm costs. Other programs must be specially designed for the area, however, so that they do not create environmental or economic problems in years to come.

In order to prevent farm foreclosure and agricultural problems from destroying the two countys' economies, the area needs to promote new industries and jobs. The geologic resources can play a large role in creating these jobs, for the area's history and park lands are important, and can be used to create tourism, which would help solve some of the economic problems. Money from tourism, in itself, however, would not solve the area's economic problems, and long term plans must be made so that the area can develop slowly, under the supervision of plans that take into consideration the long term economic and environmental choices that the area must face.

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